

Appendix 13-C

Water Balance Analysis

Table of Contents

Table 13-C.1. Monthly Precipitation Normals (Inches)	4
Table 13-C.2. Potential Monthly Evapotranspiration (Inches)	4

The water balance analysis helps determine if a drainage area is large enough to support a permanent pool during normal conditions. The maximum draw down due to evaporation and infiltration is checked against the anticipated inflows during that same period. The anticipated drawdown during an extended period of no appreciable rainfall is checked as well. This will also help establish a planting zone for vegetation which can tolerate the dry conditions of a periodic draw down of the permanent pool.

The water balance is defined as the change in volume of the permanent pool resulting from the potential total inflow less the potential total outflow.

$$\text{change volume} = \text{inflows} - \text{outflows}$$

Where: *inflows* = runoff, baseflow, and rainfall.
outflows = infiltration, surface overflow, evaporation, and evapotranspiration.

This procedure will assume no inflow from baseflow, and because only the permanent pool volume is being evaluated, no losses for surface overflows. In addition, infiltration should be addressed by a geotechnical report. A clay liner should be specified if the analysis of the existing soils indicates excessive infiltration. In many cases, the permeability of clayey soils will be reduced to minimal levels due to the clogging of the soil pores by the fines which eventually settle out of the water column. This may be considered in the water balance equation by assuming the permeability of a clay liner: 1×10^{-6} cm/s (3.94×10^{-7} in/sec.) per specifications. Therefore, the change in storage = runoff - evaporation - infiltration.

Example

Given:

Drainage Area:	85 ac. (Average 65% impervious cover)
NRCS RCN:	72
Precipitation P (2-year storm):	3.1 inches
Runoff, <i>Q</i> :	1.1 inches
Permanent Pool Volume:	$0.65 \times 85 \text{ ac.} = 55 \text{ ac. impervious cover}$ $\text{WQ volume} = (0.5 \text{ in.}) (55 \text{ ac.}) (12 \text{ in./ft.}) = 2.29 \text{ ac.ft.}$ Retention Basin II ($4 \times \text{WQ vol.}$) = $4 \times 2.29 = 9.16 \text{ ac.ft.}$
Permanent Pool Surface area:	2.4 ac.
Infiltration (clay liner per specs.):	$1 \times 10^{-6} \text{ cm/s}$ ($3.94 \times 10^{-7} \text{ in/sec.}$)

Find:

- (a) Draw down during highest period of evaporation.
 (b) Draw down during extended period of no appreciable rainfall.

Solution:

- (a) Draw down during highest period of evaporation: July

$$\text{Inflow} = \text{Monthly Runoff} = P \times E$$

Where: P = precipitation
 E = efficiency of runoff (assumed to be ratio of NRCS runoff depth to rainfall depth for 2 year storm)

$$= 1.1 \text{ in.} / 3.1" = 0.35$$

	<u>April</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug.</u>	<u>Sept.</u>
Precip. (in):	2.96	3.84	3.62	5.03	4.40	3.34
Evap. (in):	2.28	3.89	5.31	6.23	5.64	3.92

(From **Table 13-C.1** and **13-C.2**)

$$\text{Inflow: Runoff} = 5.03 \text{ in.} \times 0.35 = 1.76 \text{ in.} = 1.76 \text{ in.} \times 85 \text{ ac.} / 12 \text{ in./ft.} = \underline{12.5 \text{ ac.ft.}}$$

$$\text{Outflow: Evaporation} = 2.4 \text{ ac.} \times 6.23 \text{ in.} / 12 \text{ in./ft.} = \underline{1.24 \text{ ac.ft.}}$$

$$\begin{aligned} \text{Infiltration (w/ liner)} &= 2.4 \text{ ac.} \times (3.94 \times 10^{-7} \text{ in./sec.}) (3600 \text{ sec./hr.}) (24 \\ \text{hr./day}) & \\ & (31 \text{ days}) / (12 \text{ in./ft.}) = \underline{0.21 \text{ ac. ft.}} \end{aligned}$$

$$\begin{aligned} \text{Water balance (w/ liner)} &= (\text{inflow}) - (\text{outflow}) = (12.5 \text{ ac.ft.}) - (1.24 + 0.21) \text{ ac.ft.} \\ &= \underline{+ 11.05 \text{ ac.ft.}} \end{aligned}$$

$$\begin{aligned} \text{Infiltration (w/o liner); assume infiltration rate of .02 in./hr. (clay/silty clay)} &= \\ 13.7 \text{ ac.} \times .02 \text{ in./hr.} \times (24 \text{ hr./day}) (31 \text{ days}) / 12 \text{ in./ft.} &= \underline{2.97 \text{ ac.ft.}} \end{aligned}$$

$$\text{Water balance (w/o liner)} = (12.5 \text{ ac.ft.}) - (2.97 + 0.21) \text{ ac.ft.} = \underline{+ 9.32 \text{ ac.ft.}}$$

- (b) Drawdown during period of no appreciable rainfall. Assume 45 day period during July and August with no rainfall.

Inflow: runoff = 0 in.

Outflow: Evaporation = Avg. evaporation (July-Aug.) = $6.23 \text{ in.} + 5.64 \text{ in.} / 2 = 5.93 \text{ in.}$
 Avg. daily evaporation = $5.93 \text{ in.} / 31 \text{ days} = 0.191 \text{ in./day}$
 Evaporation for 45 days = $45 \text{ days} \times 0.191 \text{ in./day} = 8.61 \text{ in.}$
 Total evaporation = $2.4 \text{ ac.} \times 8.61 \text{ in.} / 12 \text{ in./ft.} = 1.7 \text{ ac.ft.}$

Infiltration (w/ liner) = $2.4 \text{ ac.} \times (3.94 \times 10^{-7} \text{ in./sec.}) (3600 \text{ sec./hr.}) (24 \text{ hr./day}) (45 \text{ days}) / 12 \text{ in./ft.} = 0.30 \text{ ac.ft.}$

Water balance (w/ liner) = $(0) - (1.7 + 0.30) \text{ ac.ft.} = \underline{1.0 \text{ ac.ft.}}$

Specify drawdown tolerant plants in areas corresponding to a depth of 2.0 ac.ft. (use stage storage curve).

Infiltration (w/o liner) = $2.4 \text{ ac.} \times (.02 \text{ in./hr.}) (24 \text{ hr./day}) (45 \text{ day}) / 12 \text{ in./ft.}$
 $= 4.32 \text{ ac.ft.}$

Water balance (w/o liner) = $(0) - (1.7 + 4.32) \text{ ac.ft.} = \underline{- 6.02 \text{ ac.ft.}}$

This basin (without a liner) will experience a significant draw down during drought conditions. Over time, the rate of infiltration may decrease due to the clogging of the soil pores. However, the aquatic and wetland plants may not survive the potential drought conditions and subsequent draw down during the first few years, and eventually give way to invasive species.

Note: A permanent pool volume of $9.16 \text{ ac.ft.} = 1.29$ watershed inches. A rainfall event yielding 1.29 inches or more of runoff will fill the pool volume.

[NOTE: The data in the following two tables should be checked and, if necessary, updated.]

Table 13-C.1. Monthly Precipitation Normals (Inches)

Station	April	May	June	July	August	September
Charlottesville	3.34	4.88	3.74	4.75	4.71	4.10
Danville	3.24	3.85	3.65	4.42	3.80	3.39
Farmville	3.03	4.05	3.41	4.34	3.99	3.18
Fredericksburg	3.05	3.85	3.35	3.65	3.61	3.49
Hot Springs	3.43	4.15	3.36	4.49	3.70	3.39
Lynchburg	3.09	3.91	3.45	4.16	3.59	3.24
Norfolk	3.06	3.81	3.82	5.06	4.81	3.90
Page County	3.84	4.77	4.41	4.50	4.34	4.81
Pennington Gap	4.25	4.83	4.09	4.77	3.76	3.67
Richmond	2.98	3.84	3.62	5.03	4.40	3.34
Roanoke	3.25	3.98	3.19	3.91	4.15	3.50
Staunton	2.82	3.60	2.95	3.49	3.67	3.46
Reagan Nat'l Airport	2.31	3.66	3.38	3.80	3.91	3.31
Williamsburg	3.01	4.52	4.03	4.96	4.72	4.25
Winchester	3.08	3.74	3.87	3.89	3.46	3.11
Wytheville	3.09	3.95	3.03	4.20	3.44	3.09

Source: Department of Environmental Services, Virginia State Climatology Office, Charlottesville, VA

Table 13-C.2. Potential Monthly Evapotranspiration (Inches)*

Station	April	May	June	July	August	September
Charlottesville	2.24	3.84	5.16	6.04	5.45	3.87
Danville	2.35	3.96	5.31	6.23	5.69	3.91
Farmville	2.34	3.81	5.13	6.00	5.41	3.71
Fredericksburg	2.11	3.80	5.23	6.11	5.46	3.83
Hot Springs	1.94	3.41	4.50	5.14	4.69	3.33
Lynchburg	2.21	3.72	4.99	5.85	5.31	3.70
Norfolk	2.20	3.80	5.37	6.34	5.79	4.14
Page County	1.68	3.06	4.09	4.71	4.26	3.05
Pennington Gap	2.14	3.59	4.72	5.45	4.97	3.60
Richmond	2.28	3.89	5.31	6.23	5.64	3.92
Roanoke	2.20	3.75	4.99	5.85	5.30	3.67
Staunton	2.00	3.52	4.77	5.52	4.95	3.47
Reagan Nat'l Airport	2.13	3.87	5.50	6.51	5.84	4.06
Williamsburg	2.27	3.86	5.23	6.14	5.61	3.97
Winchester	2.07	3.68	4.99	5.82	5.26	3.67
Wytheville	2.01	3.43	4.46	5.17	4.71	3.39

* Calculated using the Thornthwaite Method

Source: Department of Environmental Services, Virginia State Climatology Office, Charlottesville, VA